DY 50: Active Matter 5 (joint session DY/BP/CPP)

Time: Friday 10:00–12:45 Location: H18

DY 50.1 Fri 10:00 H18

Anomalous cooling and overcooling of active colloids — •Fabian Jan Schwarzendahl and Hartmut Löwen — Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany

The phenomenon that a system at a hot temperature cools faster than at a warm temperature, referred to as the Mpemba effect, has been recently realized for trapped colloids. Here, we investigate the cooling and heating process of a self-propelling active colloid using numerical simulations and theoretical calculations with a model that can directly be tested in experiments. Upon cooling activity induces a Mpemba effect and the active particle escapes an effective temperature description. At the end of the cooling process the notion of temperature is recovered and the system can exhibit even smaller temperatures than its final temperature, a surprising phenomenon which we refer to as activity-induced overcooling.

DY 50.2 Fri 10:15 H18

Active Ornstein-Uhlenbeck model for self-propelled particles with inertia — •Gia Huy Philipp Nguyen, René Wittmann, and Hartmut Löwen — Institut für Theoretische Physik II: Weiche Materie, Heinrich-Heine-Universität Düsseldorf, Germany

Self-propelled particles, which convert energy into mechanical motion, exhibit inertia if they have a macroscopic size or move inside a gaseous medium, in contrast to micron-sized overdamped particles immersed in a viscous fluid. We have studied an extension of the active Ornstein-Uhlenbeck model, in which the self-propulsion is described by colored noise, to access these inertial effects affecting their translational motion [1]. In this talk, analytical solutions of the mean displacement, mean-squared displacement and velocity autocorrelation function will be discussed for a free active particle and in more general settings including an active dimer, a time-dependent mass and various external forces.

[1] G. H. P. Nguyen, R. Wittmann, H. Löwen, J. Phys.: Condens. Matter 34, 035101 (2021)

DY 50.3 Fri 10:30 H18

A quantitative scattering theory of active particles — •Thomas Ihle[1], Rüdiger Kürsten[1], and Benjamin Lindner[2] — [1]Institute for Physics, University of Greifswald, Greifswald — [2]Institute for Physics, Humboldt University of Berlin, Berlin

We consider a particular model of self-propelled particles with Kuramoto-type alignment interactions. Starting from the N-particle Fokker-Planck equation we observe that the usual factorization Ansatz of the probability density, often called Molecular Chaos approximation, predicts a relaxation behavior which qualitatively disagrees with agent-based simulations. Therefore, we develop a scattering theory which resolves the time-evolution of the two-particle correlation function, i.e. goes beyond the mean-field approximation. The theory does not require input from agent-based simulations; it is self-consistent and leads to analytical expressions. We show that this theory predicts the relaxation behavior of the system and the transport coefficients with high precision in certain parameter ranges.

DY 50.4 Fri 10:45 H18

Hierarchical self-organization in communicating polar active matter — •Alexander Ziepke[1], Ivan Maryshev[1], Igor S. Aranson[2], and Erwin Frey[1] — [1]Ludwig-Maximilians-Universität München, München, Germany — [2]Pennsylvania State University, University Park PA, USA

Self-organization in active matter plays an important role for various biological and artificial systems. In numerous cases, inter-agent communication is a key mechanism for the formation and localization of critical structures, such as the fruiting body in Dictyostelium discoideum or aggregation clusters in quorum-sensing bacteria. Despite its importance, the specific role of communication and its interplay with self-propulsion remains largely unexplored.

We propose a model for communicating active matter that endows self-propelled polar agents with information processing and signal relaying capabilities. We show that information processing greatly enriches the ability of these systems to form complex structures, allowing them to self-organize through a range of different collective dynamical states at multiple hierarchical levels. This provides insights into the role of self-sustained signal processing for self-organization in biological systems and opens pathways for applications using chemically driven colloids or microrobots.

DY 50.5 Fri 11:00 H18

Collective transport of microparticles by active cells — •Robert Grossmann[1], Kevin Meissner[1], Fernando Peruani[2], and Carsten Beta[1] — [1]University of Potsdam, Potsdam, Germany — [2]CY Cergy Paris Université, Cergy-Pontoise, France

Motivated by the challenge of targeted delivery of micron-sized objects, we investigate a novel type of bio-hybrid active matter, composed of motile cells acting as autonomously moving agents that transport passive cargoes. The transport process is a collective phenomenon: a bead can be lost by one cell and may picked up by another one, or multiple cells transport one bead together, thereby giving rise to an intermittent, stochastic stop-and-go dynamics. Combining experiment and active matter theory, we investigate the emerging transport properties of this system. We first deduce the waiting time distributions of active and passive transport episodes from experiments with the amoeba *Dictyostelium discoideum*: whereas the duration of actual transport phases – determined by the time that cells and cargoes are in contact – are exponentially distributed, the waiting time distribution for passive periods exhibits power-law characteristics which results from the search of cells looking for immobile colloids. We predict displacement distributions and the mean-squared displacement of colloids based on the statistics of waiting times and particularly point out a crossover from normal to subdiffusive scaling. These results provide the basis for the future design of cellular micro-carriers and for extending our findings to more advanced transport tasks in complex, disordered environments, such as tissues.

DY 50.6 Fri 11:15 H18

Odd viscosity and active turbulence of hydrodynamic microrotors — •Joscha Mecke[1], Yongxiang Gao[2], Dirk G.A.L. Aarts[3], Alberto Medina[1], Gerhard Gompper[1], and Marisol Ripoll[1] — [1]Institute of Biological Information Processing, Forschungszentrum Jülich, Germany — [2]Institute for Advanced Study, Shenzhen University, China — [3]Department of Chemistry, University of Oxford, UK

Suspensions of rod-like silica colloids with a ferromagnetic head are considered in a rotating magnetic field applied parallel to a substrate. The magnetic moment is oriented perpendicular to the rod axis which implies a non-equilibrium vertical orientation to the substrate and synchronous spinning in the rotating field. We combine experiments and simulations to study the collective properties of these rotors. The hydrodynamic flows generated by the colloid rotations induce a cascade of translational motions in the neighbouring colloids. Thus, the rotors can be regarded as active matter with transport coefficients varying with local configuration and thus rotor density. The competition between hydrodynamic and steric interactions renders the translational dynamics non-monotonous in rotor density. The ensemble dynamics shows the emergence of eddies of various sizes reminiscent of turbulence. Furthermore, the rotor fluid is a realisation of a chiral active fluid with odd viscosity, that manifests itself in stress forces orthogonal to the direction of shear. In vortex flow, the stress acts like an effective pressure leading to density-vorticity correlations. Our experimental and numerical results are found to be in agreement.

DY 50.7 Fri 11:30 H18

Two-temperature activity drives liquid-crystal and crystalline order in soft repulsive spherocylinders — •Jayeeta Chattopadhyay, Sindhana Pannir-Sivajothi, Kaarthik Varma, Sriram Ramaswamy, Chandan Dasgupta, and Prabal K. Maiti — Centre for Condensed Matter Theory, Department of Physics, Indian Institute of Science, Bangalore 560012, India

We study the scalar activity induced phase separation and liquid crystal ordering in a system of Soft Repulsive Spherocylinders (SRS) of various aspect ratios (L/D). Activity was introduced by increasing the temperature of half of the SRS (labeled 'hot') while maintaining the temperature of the other half constant at a lower value (labeled 'cold'). The difference between the two temperatures scaled by the lower temperature provides a measure of the activity. We find that activity drives the cold particles through a phase transition to a more ordered state and the hot particles to a state of less order compared to the initial equilibrium state. For L/D = 5, the cold components of a homogeneous isotropic (I) structure acquire nematic (N) and, at higher activity, crystalline (K) order. Similarly, the cold zone of a nematic initial state undergoes smectic (Sm) and crystal ordering while the hot component turns isotropic. Interestingly, we observe liquid crystal ordering for the spherocylinders having aspect ratio below Onsager's limit. The hot particles occupy a larger volume and exert an extra kinetic pressure, confining, compressing and provoking an ordering transition of the cold-particle domains.

Ref:Phys. Rev. E104, 054610 (2021).

DY 50.8 Fri 11:45 H18

Spontaneous trail formation in populations of communicating active walkers — Zahra Mokhtari[1], Robert I. A. Patterson[2], and •Felix Höfling[1,3] — [1]Dept. Mathematics and Computer Science, Freie Universität Berlin — [2]WIAS Berlin — [3]Zuse Institute Berlin

How do ants form long stable trails? Despite abundant evidence that trail formation in colonies of insects or bacteria originates in their sensing of and responding to the deposits of chemicals that they produce, there is no consensus on the minimum required ingredients for this phenomenon. To address this issue, here, we develop an agent-based model in terms of active random walkers communicating via pheromones, which can generate trails of agents from an initially homogeneous distribution [1]. Based on extensive off-lattice computer simulations we obtain qualitatively the non-equilibrium state diagram of the model, spanned by the strength of the agent-chemical interaction and the number density of the population. In particular, we demonstrate the spontaneous formation of persistent, macroscopic trails, and highlight some behaviour that is consistent with a dynamic phase transition. We also propose a dynamic model for few macroscopic observables, including the sub-population size of trail-following agents, which captures the early phase of trail formation. At high densities and for strong alignment, we observe that rotating clusters ("ant mills") are more stable than trails and can swallow them up.

[1] Z. Mokhtari, R. I. A. Patterson & F. Höfling, New J. Phys. **24**, 013012 (2022).

15 min. break

DY 50.9 Fri 12:00 H18

Dynamics of microalgae in a porous environment — •Florian von Rüling, Liubov Bakhchova, Dmitry Puzyrev, Ulrike Steinmann, and Alexey Eremin — Otto von Guericke University Magdeburg, Germany

The navigation through complex environments is a task the microalgae *Chlamydomonas reinhardtii* are frequently confronted with in their natural habitats, where they encounter suspended and sedimented particles as well as rough surfaces. To investigate the motion in heterogeneous surroundings, we observe dilute and crowded active colloidal suspensions of *Chlamydomonas* in quasi-two-dimensional microstructured PDMS-channels. Arrays of cylindrical or elongated pillars with varying lattice spacing and obstacle orientation serve as artificial porous environments. The swimmer behaviour is characterised by means of velocity and orientation autocorrelation functions, trajectory straightness, velocity distributions and the reflection/transmission coefficients for the porous segments.

DY 50.10 Fri 12:15 H18

Extending the active Phase Field Crystal model to describe motility-induced condensation and crystallization — •Max Philipp Holl[1] and Uwe Thiele[1,2] — [1]Institut für Theoretische Physik, Universität Münster — [2]Center for Nonlinear Science, Universität Münster

The passive conserved Swift-Hohenberg equation (or phase-field-crystal [PFC] model) corresponds to a gradient dynamics for a single order parameter field related to density [1]. It provides a microscopic continuum description of the thermodynamic transition between liquid and crystalline states. A recent extension allows one to investigate both, vapour-liquid and liquid-solid transitions [3]. We first discuss the bifurcation and phase structure of this passive, i.e., thermodynamic model. Our subsequently introduced extension of the standard active PFC model [2] is able to describe passive and active (motility-induced) vapour-liquid and liquid-solid transitions. This is shown through a bifurcation and phase analysis based on path continuation supplemented by time simulations.

[1] H. Emmerich, H. Löwen, R. Wittkowski, T. Gruhn, G. I. Tóth, G. Tegze, and L. Gránásy. Phase-field-crystal models for condensed matter dynamics on atomic length and diffusive time scales: an overview. Adv. Phys., 61:665-743, 2012 [2] A. M. Menzel and H. Löwen. Traveling and resting crystals in active systems. Phys. Rev. Lett., 110:055702, 2013 [3] Z.-L. Wang, Z. Liu, Z.-F. Huang, and W. Duan. Minimal phase-field crystal modeling of vapor-liquid-solid coexistence and transitions. Phys. Rev. Materials, 4:103802, 2020

DY 50.11 Fri 12:30 H18

Engines driven by active fields — •Patrick Pietzonka[1] and Michael E. Cates[2] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Department of Applied Mathematics and Theoretical Physics, University of Cambridge, United Kingdom

On macroscopic scales, where trajectories of individual particles cannot be observed, active matter may appear like matter in thermal equilibrium. We discuss how the non-equilibrium character of active matter can nonetheless be revealed by using it as a working medium of engines delivering mechanical work in an isothermal environment. We focus on scalar active field theories such as the active model B as minimal continuum models for active matter undergoing a phase separation. The shape and chemical potential of droplets can be controlled through external potentials and activity patterns. We show how an asymmetric periodic activity pattern can drive a flow of active matter against an external force, thus acting as an autonomous engine. Moreover, we calculate and optimise the work that can be extracted by a cyclic engine that manipulates the activity and the potential landscape.